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Teaching Foundational Aquatic Skills to Children in Open Water Environments

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Teaching Foundational Aquatic Skills to Children in Open Water Environments

Cover Page Footnote

The research team would like to thank the following organisations and people for their invaluable contributions to the success of this program: • Coastguard Boating Education (advised on location and education activities in Harbor) • Swimsation NZ (delivered education activities in Harbor) • Surf LifeSaving New Zealand (advised on location and delivered education activities in Beach/Ocean) • Wild Earth Inc. (advised on location and delivered education activities in Beach/Ocean) • Brighton Surf LifeSaving Club (provided access to clubhouse for education activities) • Water Safety New Zealand (who part-funded the research), and especially • Participants and caregivers (for their time and willingness to volunteer for the study)

Abstract

Learning to swim in a swimming pool might not prepare water competence sufficiently for different aquatic environments. The aim of this study was to assess the effectiveness of teaching children water safety knowledge and skills in open water environments (i.e., harbor, river, and surf). The aquatic knowledge and skills of 98 children (7-11 years old) were tested in a swimming pool before, immediately after, and three months after receiving a three-day intensive education program. At pre-test, typically fewer than 50% of children achieved a high level of water safety competence. After the program, competency in each of the six tasks assessed had increased with up to 80% of participants completing the tasks unassisted. Three-month retention of these skills was generally high (i.e., competency levels were either maintained or improved). A key challenge for future research will be to untangle the influences of maturation, order effects, and the open water education.

Keywords: drowning, education, learning, retention, water competence

Background

Drowning remains a highly preventable public health threat for the 21st century according to the World Health Organisation (WHO, 2014). In Australia and New Zealand, young people appear particularly vulnerable, as children are over-represented in drowning statistics relative to other age groups (Croft & Button, 2015) and the psycho-motor skills competency of children is generally low (Moran, 2008). In 2017, there were 105 drownings in New Zealand, 90% of which were preventable (Mills, 2018). Over 80% (n = 75) of these preventable drownings were in open-water environments (rivers, sea, lakes, ponds etc.).

Despite the fact that the majority of drownings occur in open water, most teaching occurs in swimming pools, at least in developed countries (Stevens, 2016). Learning to swim in open water environments (e.g., harbour, river, surf, lake, etc.) is different than learning in an enclosed environment such as a pool for several reasons. The water in a swimming pool is typically treated and maintained at a comfortable temperature. As the water is clean it allows swimmers to see the bottom of the pool and determine (above and below the water) the approximate distance to convenient exit points. Furthermore, lifeguards or instructors typically monitor the pool environment and there are warning signs to prevent dangerous situations arising (e.g., learners going out of their depth). In contrast, most open water environments are not patrolled, with the exception of some beaches, and they may have limited information about potential dangers. Additional differentiating factors may include colder and varying water temperatures, less confined spaces, sudden changes in depth, waves, and currents, eddies and strainers (e.g., fixed objects within a current that may trap or injure someone). The weather may also have a significant and less predictable role in open water environments than in enclosed pools. Indeed, many drownings in open water result from unintended immersion in which the victim was clothed, a potentially influential factor that is only occasionally practiced in pools.

Although some public pools can simulate some features of open water environments (e.g., wave pools or ‘lazy rivers’), the large majority of pools do not have such expensive facilities. Hence, people typically learn to swim in an environment that is quite different and much more predictable than open water. It is likely that some of the differences between a controlled indoor environment and an outdoor swimming environment contribute to the panic often associated with an unplanned and sudden immersion into open water (Potdevin et al., 2019). Indeed, learning to swim within the sheltered confines of a swimming pool may create a misplaced confidence in aquatic ability that may not transfer well to other aquatic environments (Stallman et al., 2008). The motor learning literature has highlighted this issue in recent times and recommended water safety instructors to implement representative learning designs to optimize skill transfer (e.g., Guignard et al., 2020).

Langendorfer and Bruya (1995) proposed that a basic level of water competence is required for humans to recreate safely in aquatic environments. Their pioneering work explained that water competence emerges as a consequence of the interaction between three types of constraints (i.e. personal - e.g., age, confidence, and fitness; environment - e.g., temperature, currents and waves; and task - e.g., clothing, flotation aids and the desired goal of the activity). As such, constraints can change rapidly in open water; an apparently competent individual may find themselves in difficulties if they lack awareness or knowledge of their environment. Indeed, even the strongest swimmers are vulnerable to factors such as cold water, waves and currents (Button et al., 2015). Wiggins et al. (2019) have recently shown that familiarity with water recreation environments improves a person’s ability to identify water safety cues. It seems important that a basic level of water competence includes the capacity to adapt skills to different types of aquatic environments (Stallman et al., 2017). Langendorfer (2015) suggested that “to be ready to survive in open water or surf especially in colder temperatures, a swimmer needs repeated experience in related environments” (p. 6). Therefore, it seems likely that education of water competency may be best conducted in a range of aquatic environments. Unfortunately, insufficient research has considered the location of swimming lessons as a potentially confounding variable influencing drowning risk (Brenner et al., 2009; Rahman et al., 2014; Wallis et al., 2015).

The discrepancies between aquatic competencies demonstrated in different environments have been highlighted by Kjendlie et al. (2013), who were interested in how the presence of waves influences aquatic skills. They recruited 66 children aged 11 years (with previous swimming knowledge) to perform identical tests in the same swimming pool with either a calm water surface or a simulated open water, ‘wavy’ environment (30–40 cm amplitude waves). Skill tests consisted of 200-m swimming time trials, a 3 min floating test, a diving entry test, and a rolling entry test. Only 59% of the sample was able to function in the wavy water course (compared to 80% in calm conditions). Tests in the waves clearly showed several performance decrements, with 14% longer time to complete the swimming test and 21%, 16% and 24% lower scores for rolling entry, diving and floating tests, respectively. Such findings prompted the suggestion that children “should not be expected to reproduce swimming skills they have performed in calm water with the same proficiency in unsteady conditions during an emergency” (Kjendlie et al., 2013, p. 303).

Whilst there is now general agreement about what information and skills should be taught to children, there are few published datasets on the current levels of water competency that children possess (Button et al., 2017). There is also a lack of research surrounding how to optimize the retention of water safety skills and knowledge in children. This situation led Langendorfer (2015) to lament that more research is required to confirm whether learning to swim has an inoculation effect in terms of aiding drowning prevention. Existing efforts to better understand the impact of water safety education have focused almost exclusively on the immediate effects on knowledge (e.g., McCool et al., 2009) and not on its long-term retention. Similar fields of investigation that pertain to educating children in safety awareness and risk identification also lack investigative insight into how best to consolidate such competencies over the lifespan (Hillier & Morrongiello, 1998). Button et al. (2017) analyzed the impact of an education program (10 * 1-hour weekly lessons), taught in swimming pools, on water competencies of New Zealand children. It was predicted that teaching children a range of water safety skills (e.g., putting on a lifejacket, simulated rescue, treading water) alongside swimming education in a pool would facilitate learning. Whilst those findings were generally encouraging, the improvements were fairly modest and fewer than 50% of children exhibited high competency in each of the tasks at post-test. Also, although children’s knowledge of risks and emergency response had increased immediately after the education program, this knowledge was not retained after 3 months (Button et al., 2017).

The question evaluated in the present study was whether it is effective for children to learn aquatic knowledge and skills in open water environments. To our knowledge there is no other published research concerning how robustly aquatic skills are learnt in such environments. Based on previous research the following predictions were made: (H_1) Prior to the education program, the water safety skill competency of young children will be varied but overall quite low i.e., less than 50% of children would exhibit high competency in core tasks (see Button et al., 2017; Moran et al., 2008); (H_2) The water safety skill competency of children would improve following an education program taught in open water environments, and; (H_3) competency would be retained for at least three months.

Method

Participants

Recruitment was largely via advertisements placed at schools and on social media sites used by parents. Children aged between 7 and 11 years at the beginning of the testing period were invited to attend a free water safety program provided over a school summer holiday period. Interested parents and caregivers (hereafter termed caregivers for brevity) were directed to a website that provided full details of the program and an option to sign up their child/children. Caregivers were sent instructions about how to schedule their child for testing via an online registration system. In total 120 children were initially recruited, however due to illness and lack of availability only 98 (82% original sample) attended all the required testing sessions (see Table 1). Each child and associated caregiver provided written informed consent before participating.

Table 1

Mean participant characteristics at pre-test (standard deviation)

Sex	N	Age yrs	Height m	Weight kg	Est. pool visits N / yr	Est. open water visits N / yr	Self-reported swimming ability (N)		
							Fair	Good	Advanced
F	44	9.3 (1.3)	1.39 (0.10)	34.3 (9.1)	56 (38)	41 (65)	5	26	12
M	54	8.8 (1.3)	1.36 (0.10)	32.6 (10.0)	55 (46)	39 (67)	7	36	9
Total	98	9.0 (1.3)	1. 37 (0.10)	33.3 (9.6)	55 (42)	40 (66)	12	62	21

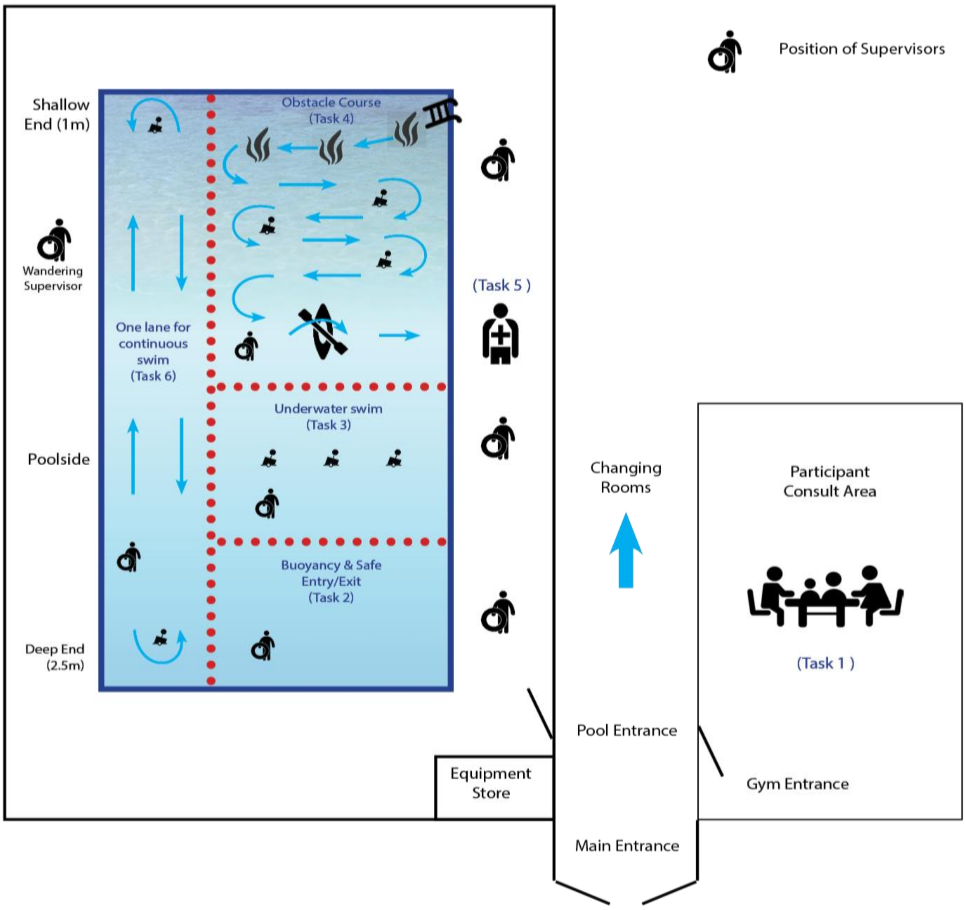
Note. Children estimated their own swimming ability as Fair (i.e., "I would struggle to swim 25 m unaided"), Good (i.e., "I can swim 100 m unaided") or Advanced (i.e., "I can swim more than 200 m unaided"). Swimming ability responses from 3 children were not recorded, hence the sub-total of 95.

Procedures

The following experimental procedure was approved by the participating institution's human ethics committee. Participants and their caregivers attended the same indoor 25-m swimming pool (Figure 1) on three occasions (i.e., pre-test, post-test, and then three months later for a retention test). The day after the pre-test, participants began a 3-day open water education program, and were then tested again in the swimming pool on the final day of the week, and then re-tested 3 months later.

Figure 1

Diagram of the typical pool facility set-up to accommodate all six tasks during pre- and post-intervention assessments, and the placement of supervisors



Note. The typical ratio of supervisors to participants was 4:6.

Phases 1, 3 and 4: Competency testing

Before each testing session, participants were instructed to refrain from heavy exercise for at least one hour. Upon arrival at the pool, the children went to change into their typical swimming costumes underneath a pair of their own light cotton pajamas while the experimental procedure was explained to their caregiver. Anthropometric data and perceived general swimming competency were collected before testing commenced. Once the participant was ready to begin testing the caregiver was asked to leave the swimming pool and return to collect their child/children in one hour. The purpose of requiring the caregiver to absent themselves was to prevent them from influencing their children's responses to the tasks.

For each of the three test phases, participants were asked to attempt six tasks (Table 2). Each task was comprised of multiple water competencies meaning that no water competency was tested in isolation, however this was deemed more representative of the confluence of competencies typically required. The order of the tasks was randomized except for the knowledge quiz (first) and propulsion task (last), which were ordered consistently for logistical reasons. Participants were typically tested in small groups of two to six children, although occasionally one child was tested alone (with assistance from a lifeguard). Children were quasi-randomly allocated to testing groups of variable size depending upon the preference of the caregivers in terms of the time slot that they chose. Furthermore, depending upon the number of participants allocated to each testing session, between one and four lifeguards were present in the water to provide supervision where necessary. Once all six tasks had been completed the participants were asked to rank the perceived difficulty of the six different tasks. They were then collected by their caregiver. A caregiver's survey was administered after the completion of the retention test to collect both quantitative and qualitative feedback.

Table 2

Overview of six water safety tasks and assessment competencies

Task	Task Description and *Water Competencies Assessed (italics)*	Assessment system (Grade 1-4)
1. Knowledge (Quiz)	A series of 3 multi-part questions prompted by pictures of various aquatic environments (e.g., ocean, river, and harbor). The knowledge tested included: 1. Can describe the open water conditions (e.g., temperature, current, waves, obstructions) and how these features influence risk 2. Demonstrates awareness, understanding and attitude towards water safety rules, hazards and risks 3. Recognizes an emergency for oneself or others and knows what to do i.e., how/who to call for help *Knowledge of environments, awareness of risks, and how to respond in emergencies*	Grade 1 = 13-12 correct 2 = 11-8 correct 3 = 7-4 correct 4 = 3-0 correct Note: Participants could provide up to 13 correct answers

2. Safe entry/exit & buoyancy	This task took place in the deep end of the pool (2.5 m). Participants were first asked to climb into the water without using the ladders and complete as much of the following task list as they could: 0-1 min: Float on their back 1-3 min: Tread water in calm conditions 3-4 min: Continue treading water whilst a hose with a spray attachment was switched on to simulate rain 4-5 min: Continue treading water whilst the lifeguard simulated waves using a paddleboard 5 min: If all tasks above were completed, the participants had to call for help with one hand in the air before swimming to the side and climbing out of the pool *Check environment for hazards, safe entry and exit to water, buoyancy/flotation, treading water*	1 = Completed all tasks correctly without assistance 2 = Stayed afloat for 1 min and trod water for up to 1 further min 3 = Stayed afloat for up to 1 min 4 = Could not complete any aspects of task without assistance
3. Submersion	Participants climbed from poolside into the water. They were then asked to hold their breath, surface dive completely underwater, and swim to a brightly colored ring (situated 6 m away from them and approximately 1 m underwater) and retrieve it. They then resurfaced, gave the ring to a lifeguard and then swam back to the same side of the pool they entered and exited. Note that swimming goggles were optional but the researchers recommended that they were not worn. *Safe entry and exit to water, surface dive, underwater swimming, breath control*	1 = Retrieved the ring without prior resurfacing or requiring an additional breath 2 = Retrieved the ring but an additional breath was required 3 = Retrieved the ring with multiple breaths required 4 = Unable to retrieve the ring

4. Obstacle course	Participants were asked to complete an obstacle course whilst wearing their swimming costume under a pair of full-length pajamas. The obstacles were located in the shallow end of the pool (see Figure 1). The course consisted of 3 ‘bushes’ of artificial seaweed placed 2 m apart, 3 brightly colored buoys configured in a zigzag, and a plastic kayak. The children climbed into the pool using a ladder, then waded (or swam if they chose to) through the seaweed. They then had to swim around the buoys, without touching the bottom of the pool. Finally, they were asked to climb over the supported kayak, then grab and be towed by a buoyancy aid before exiting at the side of the pool. *Clothed swimming, general water orientation competence, propulsion*	1 = Completed all tasks successfully independently 2 = Completed all tasks, required assistance or touched sides or bottom 3 = Could not complete all tasks, required assistance often, but finished the course 4 = Could not complete the course
5. Simulated rescue	At the side of the pool the children were asked to choose one of three different lifejackets appropriate to their size (small, medium, large). They then had to put the lifejacket on and secure two plastic buckles. The instructions were to secure the jacket tightly so that it would not slip over their head if pulled up by the experimenter. Once the life jacket was put on, the child had to pick up a leashed buoyancy aid and throw the aid to their partner in the water (see Obstacle course above). They then pulled their partner to the side and helped them to exit the pool. *Chooses and fits lifejacket competently, throws buoyancy aid appropriately, can assist an in-water partner to safety*	1: Independently chose correct life jacket, secured it tightly and threw buoyancy aid to partner 2: Completed all tasks with advice from researcher 3: Completed all tasks with physical help from researcher 4: Unable to complete all tasks

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6. Propulsion	Brightly colored buoys were placed at either end of the pool. The children were asked to enter the pool and then swim continuously up and down the pool around the buoys for 5 min. The instructions were not to touch the sides of the pool or floor if at all possible. Participants were told they could use whichever stroke they preferred. They wore their normal swimming costumes and, if they chose to, their goggles. Participants performed this activity in groups of 2-6 other children with lifeguards in close proximity. *Safe entry/exit, breath control, water orientation competence, propulsion competence*	1 = Swam continuously for 5 min without assistance 2 = Swam at least 100 m but stopped once or twice 3 = Unable to complete either 100 m or 5 min, requiring multiple rests 4 = Unable to complete either 50 m or 2½ min, requiring multiple rests

Phase 2: Water Safety Program.

The water safety education program was delivered over three consecutive days during the school summer holidays in three different open water environments (i.e., harbor, river, and surf). The program was delivered by teams of 'expert educators' with comprehensive experience of the environments and appropriate teaching qualifications (see Acknowledgements). Each educator organization was committed to providing a high quality, safe learning environment for the children and a memorandum of understanding detailing shared expectations and responsibilities was signed by all parties representing the 'research team' prior to the program. A planning phase of approximately three months preceded the study, during which the research team discussed in depth factors such as the goal of the education program, who else was involved in delivery, and the nature of the research process the program was embedded within. Indeed, a collaborative discussion process with each educator organization covered: which water competencies they should be teaching; how they might achieve that through sample lesson plans; and also, how the children were to be assessed by the research team before and after the program. Additionally, safety issues and logistics such as supervision ratios, contingency plans, and equipment requirements were also planned in advance with each organization.

For each open water location, children were divided into small learning groups of approximately 10-20 for logistical reasons with appropriate ratios of children to supervisor for water activities (no more than 2:1). Children with low perceived swimming competence at pre-test were generally grouped together and the activities undertaken were less advanced than those completed by the more competent children. Table 3 provides a brief summary of the activities completed at each location and the associated water competencies emphasized.

Table 3
Summary of open water education activities and associated water competencies developed

Environment	Activity description (duration)	Task / Water competencies emphasized
1a. Harbor club (indoor)	Group discussion about harbor environment and necessary preparation (45-60 min) - Tide and other environmental hazards - W.E.T. analogy (Weather, Equipment, Tell someone) - Sorting Box (useful vs. non useful items for taking on boat trip)	1. Knowledge (of environments, awareness of risks, and how to respond in emergencies)
1b. Harbor club and in-water (indoor & outdoor)	Simulated rescue discussion and practical demonstrations (45-60 min) - Choosing and fitting life-jackets correctly - Throw rescue with buoyancy aids - Small group huddles (3-4 children) - HELP (Heat Escape Lessening Position)	5. Simulated Rescue 2. Safe Entry / Exit and & Buoyancy
1c. Harbor in-water (outdoor)	Inflatable rescue boat (IRB) activities (60-90 min) - Balancing boat - Dropping backwards off boat into water - Overturned IRB (finding air pockets) - Swim to shore	1. Knowledge, 3. Submersion, 4. Obstacle Course 6. Propulsion
2a. Riverbank	Create a stream in the riverbank and discuss potential dangers, e.g., current, eddies, strainers etc. (30 min)	1. Knowledge
2b. River	Feet first float downstream e.g., Entry and exit, floating, breathing, moving left or right whilst on back, survival swim position (30 min)	2. Safe Entry / Exit & Buoyancy

2c. River	Strainers and how to deal with them (30 min) - Aggressive swim to avoid the strainer - Swimming over the strainer	1. Knowledge, 4. Obstacle Course 6. Propulsion
2d. River	Discussion of hazards in a river environment and potential changes (30 min) - Deciding if river is safe to cross - How to safely wade across river (individual and small groups of 3-4)	1. Knowledge, 4. Obstacle Course
2e. River	Rope throw rescue (30 min) - Coiling a weighted rope and throwing it to rescue someone - Adopting and maintaining feet first back survival swim position whilst being rescued - Safe exiting of river	2. Safe Entry / Exit & Buoyancy 5. Simulated Rescue
3a. Beach club house (indoor)	Group discussion of beach/ocean safety rules (30 min) - Flags - Adult supervisor - Listen to lifeguards - Never swim alone, “If in doubt, stay out”	1. Knowledge
3b. Beach club house (indoor)	Discussion of rips and rescues (30 min) - What are rips? Where rips form - How to escape a rip - How VHF Radio Works - Marine Distress Channel, “Mayday, Mayday, Mayday”	1. Knowledge, 5. Simulated rescue
3c. Beach (outdoor)	Rip sculpture activity (30 min) - Small groups sculpt mini-working rip using sand by water edge, watch for rip features as water recedes - Name the different features of the rip	1. Knowledge

3d. Ocean (outdoor)	Tube rescue relays (30 min) - Mock rescues using tubes - Person being rescued to raise hand to signal for help - Discuss what else can be used to help stay afloat	2. Safe Entry / Exit & Buoyancy 5. Simulated Rescue
3e. Ocean (outdoor)	Water / surf activities (30-45 min) - Wading through waves - Over & Under (waves) Run (surf) (Beginner) - Dolphin diving under waves & body surfing (Advanced only) - Floating (with and without body board) - Body Boarding	3. Submersion, 4. Obstacle Course 6. Propulsion

Note. The education program was delivered in mid-Summer and the ambient conditions were consistently favorable (i.e., approximately 20-25ºC, sunny, settled). The Harbor activities were undertaken close to a yacht club boat ramp (sloping entry) and jetty (2.5 m depth). The water temperature was 17-19ºC, activities were undertaken at high tide and there was no local current. The River activities were undertaken in a gorge with walkable access to the water from a gravel, stony riverbank. The river flow was low, there were several swimming holes with average depth of 1.6 m and water temperature of 15-18ºC. The Beach/Ocean activities were undertaken at a popular lifeguard-patrolled beach. The water temperature was 17-19ºC and the swell conditions were light to moderate.
For more information about these locations, see: www.yachtingnz.org.nz/clubs/yacht-club/otago-yacht-club (Harbor); www.theswimguide.org/beach/6221 (River); www.theswimguide.org/beach/6222 (Beach/Ocean).

Data Analysis

For the pre-test, post, and retention tests, each participant's water competencies were visually assessed and recorded manually by one of four trained assessors. The assessors (including authors 1 and 4) were either senior researchers or post-graduate students, each with tertiary qualifications in Sport and Exercise Science. The training comprised a one-hour session in which the six tasks were demonstrated in turn to the assessors by a highly competent child and assessors were provided with instructions about how to apply the 4-point assessment rubric for children of different competency levels (i.e., Grades 1-4, see Table 2). To facilitate grading consistency amongst the assessors, the first four participants assessed in each round of testing were graded by pairs of assessors before subsequent participants were graded individually. The assessors marked competency scores on a separate assessment sheet for each participant following their completion of each task. On the same sheet the assessors also recorded the participant's ranking of task difficulty after they had completed all six tasks.

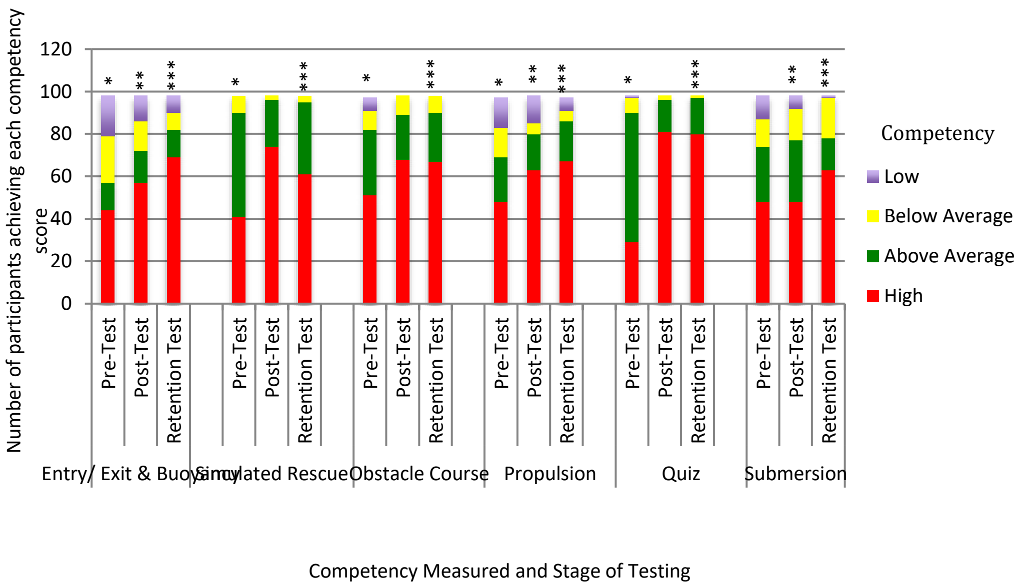
Data were transcribed from written form into Microsoft Excel, and analyzed using SPSS (Statistical Package for the Social Sciences, Version 23.0. IBM®). As the data were typically ordinal (i.e., 4-point scale) non-parametric statistics were used for comparisons. Friedman's N related samples tests were used to compare for a main effect of time with three levels. Post hoc analysis with Wilcox signed-rank tests was conducted with a Bonferroni correction for multiple comparisons ($p < .017$).

Results

The competency data for all six tasks is summarized in Figure 2. At pre-test, typically fewer than 50% of children achieved a high level of water safety competence. Significant improvements ($p < .017$) in terms of the number of competent children were found for all six tasks typically from pre- to post-test and/or from pre-test to retention (Figure 2). The submersion task was the only activity not to result in a significant increase from pre- to post-test. In general, there was an increased number of participants that achieved the higher competence grades by the post-test, and then retained that increased performance at the retention test.

Figure 2

Competence achieved on the six tasks during the three stages of the program (pre-test, post-test and retention test)



Note. * Significant difference between pre-test and post-test. ** Significant difference between post-test and retention test. *** Significant difference between pre-test and retention test.

When the overall competency data are presented by gender (Table 4) there appears no consistent trends for either boys or girls to benefit more from the education program. It is notable that the post-test to retention test changes were typically positive (further improvements). These data indicate that the level of retention of skills three months after completing the program was generally good. The simulated rescue task had a notable reduction in performance from post-test to retention (i.e., -14%, although this difference was not significant) indicating that further consideration of the retention of these important skills may be required.

Table 4

Changes in competency expressed as percentage of participants improving (+) or declining (-) between tests. Changes presented by gender, with overall mean.

Task	Sex	Pre- to Post Test	Pre- to Retention Test	Post- to Retention Test
Knowledge	Female	37	39	4
	Male	30	28	-2
Mean		33	33	0
Buoyancy	Female	24	36	15
	Male	11	22	12
Mean		17	28	13
Submersion	Female	1	15	14
	Male	7	16	9
Mean		5	15	11
Obstacle Course	Female	18	11	-8
	Male	19	21	2
Mean		19	17	-2
Simulated Rescue	Female	30	17	-18
	Male	22	13	-10
Mean		25	15	-14
Propulsion	Female	19	20	1
	Male	10	25	16
Mean		14	23	10

Table 5
Perceived difficulty of the six tasks during pre-test, post-test and retention-test (from 1 = 'easiest' to 6 = 'most difficult')

Task	Pre-test		Post-test		Retention Test	
	Mean	Ranking	Mean	Ranking	Mean	Ranking
Knowledge	3	4	4	4	4	4
Buoyancy	4	5	4	6	4	6
Submersion	3	3	3	3	3	3
Obstacle Course	2	1	2	1	3	1
Simulated Rescue	3	2	3	2	3	2
Propulsion	5	6	4	5	4	5

The children ranked the Obstacle Course (followed by the Simulated Rescue task) as the easiest task to complete (Table 5). At Pre-test, the Propulsion task was ranked 'most difficult' followed by the Buoyancy task. By Post-test and Retention, these two tasks were still ranked as the hardest tasks albeit with the Buoyancy task adopting the most difficult ranking. Competency data for each task are described in detail in the following sub-sections.

Knowledge
The pre-test data indicate that nearly 90% of the children gave correct answers to at least eight out of 13 questions (grades 1 and 2) in the quiz. The children improved their overall Knowledge competency from pre- to post-test and retained this improvement in the retention test. At pre-test only 30% of children achieved high competency (at least 12 from 13 answers correct), whereas at post-test 83% did so, and this was maintained at 3 months (82%).

Buoyancy
Pre-test competency was varied for the buoyancy task (Figure 2). Less than half the group could complete five min of continuous floating and treading water (45%), and 41% of participants chose not to float unsupported for up to 60 s. By post-test, the number of competent children had increased, with 58% of children now attaining a grade 1. A further significant improvement was found at the retention test, with 70% of participants successfully completing the task and only 17% unwilling to float for 60 seconds.

Submersion
Submersion was the only task without a significant improvement from pre- to post-test (Figure 2). However, submersion competency did significantly improve in the retention test compared to the pre-test. In the retention test approximately two thirds of participants (64%) could swim along the bottom of the pool floor to retrieve a submerged colored ring and only one participant was unable/unwilling to complete a surface dive and retrieve the ring (grade 4).

Obstacle Course

Approximately half of the children (52%) could complete the obstacle course without assistance at the pre-test. The children improved their overall competency from pre- to post-test (52 to 69%) and retained this performance level without further improvement in the retention test. Six children at pre-test refused to or could not complete the course but by post-test and retention no children were at grade 4.

Simulated Rescue

Participants were mostly able to complete the simulated rescue at pre-test (grade 1 = 41, grade 2 = 49) although many needed advice about how to secure their lifejackets or throw the buoyancy aid to their partner. By the post-test, 75% of participants scored a grade 1, which was a significant improvement. The performance level at the retention test (62% at grade 1) was still significantly better than the pre-test, indicating the improvement had been retained after three months.

Propulsion

Propulsion competency improved from pre- to post-test and that standard was retained three months later. At pre-test, 49% of children could swim continuously without assistance for five min, increasing to 64% of children by the post-test, and 68% by the retention test.

Caregivers' Survey

Sixty-three caregivers completed a program evaluation form whilst children took part in the three-month retention test. Several caregivers brought more than one child to the program, which is why fewer than 98 responses were provided.

Caregivers appreciated that the program provided opportunities for children to learn about dangers and safety skills across different environments and overall were pleased with the experiences their child/children had during the program. Although one caregiver highlighted they would have liked more information on the content of the program, the general consensus was that the program was well run. Sample free-text comments from the questionnaire include:

> "Awesome program. All children should have the opportunity to experience the program. Outdoor swimming is very different to swimming in a pool"
>
> "The program is so DIFFERENT from "swimming lessons" and much more applicable to our lifestyle"
>
> "A great program. Good to see the children experience real life situations".
>
> "Fabulous program. Children were engaged throughout all sessions and felt more confident as a result. It was fun for them too."

Two caregivers highlighted that they felt the better swimmers could have been challenged a bit more in some of the activities and one caregiver felt that the size of the subgroups that children were taught in could have been smaller. However, the general consensus was that the needs of the various children were well catered for and that children learned lots of valuable water skills, even those who were already strong swimmers (Figure 3).

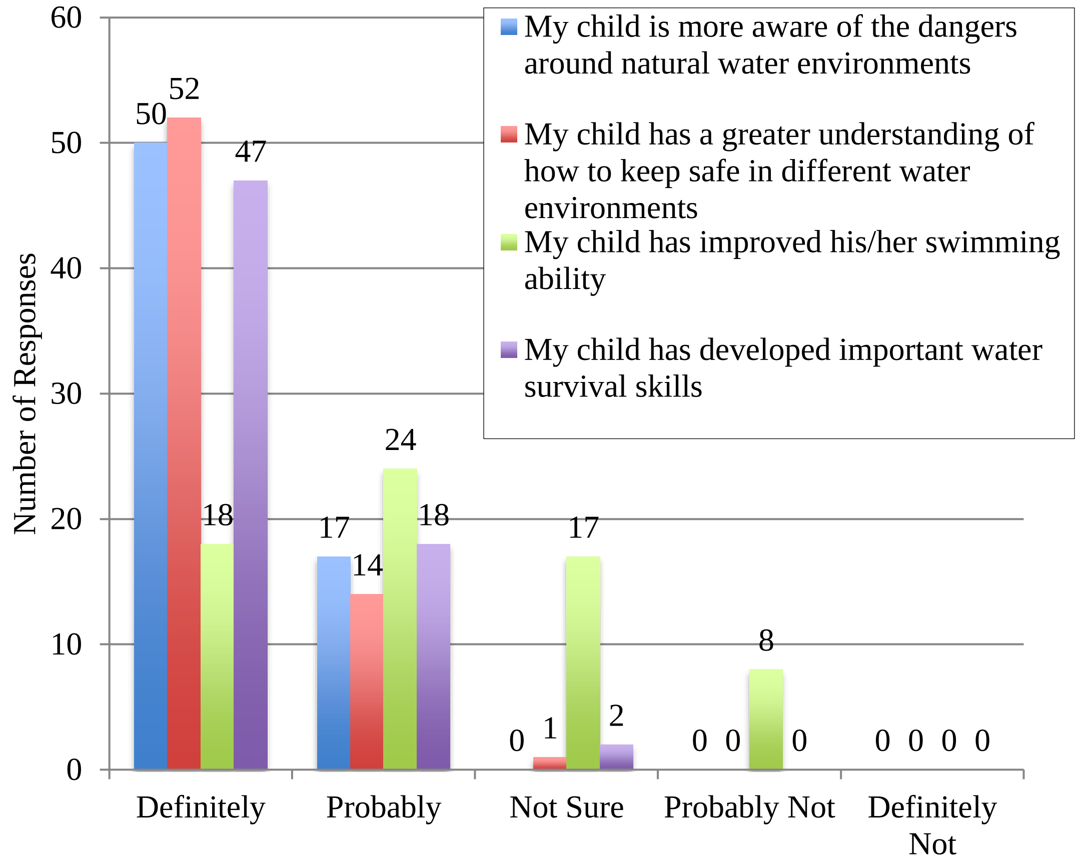
> "This course has improved our child's general swimming confidence. She has swum in deep water, which she would never have attempted before the course"

> "Both [my children] came home saying they had learnt a lot and feeling more confident in water that wasn't just in a pool."

> "We are not a water sports family, and our child is not confident in the water. This allowed her to learn skills that we don't have the knowledge to teach her."

Figure 3

Likert responses (1-5) to the statement: "As a result of being involved in the program, I feel ..." (see legend for specific comments)



Whilst many caregivers indicated that they would be willing to pay for their children to attend a water safety course like this one in the future, a common issue raised was how the cost and logistics of transporting children to the various venues could be prohibitive:

> "The travel to the different places was a huge cost to us. Any extra cost we would most likely not be able to do this program. We did really appreciate it."
>
> "Very happy we got to take part [in the program]. Had it cost money we probably couldn't have done it as we are on a very tight budget. …Government should subsidise water safety lessons. So important in our country … summer holidays spent in and around water"

Many caregivers highlighted how important it was that educators emphasize the practice of water safety skills (not just swimming), alongside the need for such a program to be widely available:

> "Awesome idea and strongly agree with the hypothesis that water safety skills as important as swimming ability."
>
> "The whole course was great and it would be really good if schools could implement this program so lot more children could benefit from it."
>
> "Would be keen on my children taking part in something like this on a regular basis to keep it fresh. Perhaps courses throughout the school term or school holidays."
>
> "[The Program is] a great opportunity for children to improve their skills and be safer in our environment. Would be great if every child could have this experience"

Discussion

It is important to acknowledge that the experimental design lacks a control group and spans a considerable period (three months) over which maturation and practice may have influenced the participants' water competency. The conclusions of the study must necessarily be tempered against such limitations. Nevertheless, to our knowledge this is the first published dataset concerning the efficacy of education in open water settings (particularly with a focus on psycho-motor skill retention) and as such represents a valuable addition to the literature.

H_1: The water safety skill competency of young children will be varied but overall quite low

On first inspection there appears to be strong support for this prediction. At pre-test, typically less than 50% of children achieved a high level of competence on the six water safety tasks (Figure 2). However, when the two highest competency grades (i.e., grades 1 and 2) are combined, 50-90% of children were competent depending upon the task. Relatively few children demonstrated the two lowest competency grades although it should be noted that the two tasks rated most difficult had up to 42% of children graded at level 3 or 4 (Buoyancy: 42%, Propulsion: 29%). As we discuss later, it is possible that selection bias may have contributed to the wide variation of competency levels found (see Limitations section).

In support of previous research (Button et al., 2017), the water safety competencies of 7-11 year old New Zealand children were spread across a wide continuum of skilled behavior yet overall is quite low relative to several of the competency standards recommended by New Zealand’s Water Skills for Life program. It is particularly concerning that approximately 60% of participants failed to complete the 5-min continuous swim and 41% an unsupported floating exercise without receiving additional help. The propulsion task performances in this study are similar to those reported in previous studies of New Zealand children which demonstrated that more than half could not swim 100 m continuously in a pool (i.e., Moran et al., 2008: 54% of children; Button et al., 2017: 62% of children). These findings also corroborate a recent review of New Zealand schools swimming education programs (Stevens, 2016), which found that only about a quarter of schools are providing the minimum accepted standard of eight swimming lessons per year. The fact that nearly half of participants chose not to complete up to 1-minute floating on their back unsupported reflects a lack of confidence amongst these participants as almost all prepubescent children have the anatomical capacity to float (Stallman et al., 2017). The large variation in aquatic competency of children remains a concern in New Zealand where open-water features are so abundant and accessible.

H_2: The water safety skill competency of children will improve following a one-week intervention program taught in open-water environments

There was strong support for the second hypothesis, with children improving in competency between pre- and post-test for five of the six tasks tested. The only task that didn’t show a significant number of children improve by post-test was the Submersion task (underwater swim to retrieve an object) although there was improvement at the time of the retention test for this activity. Participants were allowed to wear swimming goggles during testing if they chose (although many chose not to) so it does not seem likely that impaired vision underwater influenced these findings. Whilst underwater swimming featured in the Beach and Harbor sessions of the program (Table 3), the distance/depth swum underwater and requirement for all children to retrieve an object was not imposed. A more explicit focus on the practice of submersion activities within aquatic education programs in the future seems necessary.

The extent of improvements was typically limited to one competency band (i.e., grade 2 to grade 1). For some of the tasks (i.e., Knowledge, Obstacle

Course, and Simulated Rescue) at least 80% of children were graded at 1 or 2 by the time of post-test. The task showing the most frequent improvement in competence was Knowledge (the Quiz). At pre-test, only 30% of children achieved a high competency score in the quiz (at least 12 correct answers from 13 questions) yet by the post- and retention tests the proportion of highly competent children had increased to 83% and 82% respectively. These findings are particularly encouraging and indicate that knowledge of water conditions, safety considerations and emergency procedures may be effectively taught in open water environments. In a previous study (Button et al., 2017), it was shown that 10 weeks of lessons taught in swimming pools was effective in improving water safety knowledge and competency (Table 6). The findings of the current study indicate that similar levels of improvement can be obtained from an education program conducted over three days (albeit with a similar overall duration of 10 hours). Furthermore, rather than being taught in swimming pools or at schools (Wallis et al., 2015), the current study has shown that it is possible to improve water safety competencies through education delivered in open water environments.

Table 6

Percentage of participants obtaining highest competency grade from Button et al.'s study (2017) in which children (N = 48) were taught water safety knowledge and skills in a combination of swimming pools and school classrooms.

Phase	Knowledge	Entry/exit & buoyancy	Submersion	Obstacle course	Simulated rescue	Propulsion
Pre	15	23	23	31	23	38
Post	33*	44*	23	40	35	44
Retention	8**	40	38	46**	38	42

Note. High competency grade = 1 out of 4. * Significant difference between pre and post; ** significant difference between post and retention. Table reproduced from Button et al. (2017) with permission of Water Safety NZ.

H_3: The improvement in water safety skill competency will be retained for at least three months

There was strong support for the final hypothesis. The number of children successfully completing all six competency tests significantly improved from pre-test to the retention test. By the time of the retention test, the percentage of children achieving the highest competency grade had increased to at least 60%. Whilst the participants' activities were not controlled or monitored following the education program, this impressive level of retention is very encouraging. In contrast, Button et al. (2017) found that skill and knowledge retention following a pool-based intervention was not uniformly maintained. Notably in that study, the Quiz (knowledge) competency decreased following three months to a level similar to that observed in the pre-test (Table 6). Several factors may have contributed to the strong retention effects found in the present study, including a potential order effect, maturational changes over three months, and the intense practice schedule in addition to the open water environments used.

The only task in which competency decreased from post-test to the retention test (although not significantly) was the Simulated Rescue. Important components of this task included the requirements to put on and tighten a lifejacket as well as throw a buoyancy aid to a partner. Assessors noted that several of the younger participants physically struggled with these elements particularly when the children were cold and/or tired (i.e., to undo and tighten plastic buckles). Hence it is possible that the task was physically too demanding for many of the younger children in the sample. Although the children could have asked for an adult's help to complete this task they typically preferred not to. It is also possible that insufficient practice was provided for this fundamental skill during the education program. Further investigation in future work is recommended.

Limitations

A potential limitation of the study was that the sample of participants obtained for the study was not representative of the general population (i.e., the children may have possessed a moderately high aquatic competency) due to sampling bias. In the recruitment process we relied on caregivers voluntarily signing their children into the program. As such children with very low competency may have been less likely to participate due to their pre-existing fears of water. Indeed only 12 of 98 children self-reported their swimming competency as 'fair' or less than 'good' (Table 3). Hence, it seems a strong likelihood that the procedure of recruiting participants in the present study resulted in sampling bias towards more competent participants, an issue which would need to be addressed in future work. Despite this limitation and given that pre-test competency levels may have already been reasonably high it is notable that the program was <u>still effective</u> in improving knowledge about aquatic environments and emergency procedures as determined via the quiz. However, the potential of sample bias renders the confirmation of hypothesis 1 even more concerning in terms of the possibility that New Zealand children may have poorer competency than reported here.

A further limitation of the study was the reliance on subjective measures of water competency. In order to obtain reliable analyses of competency a 4-point Likert scale based on the previous study of Button et al. (2017) was employed. The actual competency ratings were based on the observations of four trained assessors. Whilst consistent cross-checking of data occurred between assessors, a more reliable and sensitive method might have been to video the children performing the tasks and to subsequently rate performance by an independent expert panel. In the interests of maintaining a 'natural' testing environment and minimising the extent of surveillance perceived by the children, the observational technique was deemed the best compromise in the present study. Exploring means to improve the reliability and sensitivity of water safety competency measures would be a useful exercise for future research.

Furthermore, it is also important to acknowledge that all the water safety tests were conducted in a supervised swimming pool. Within the confines of the experimental design it is not possible to conclude that children taught in open water environments will effectively reproduce their skills in such environments when required. For safety reasons and the logistical barriers of conducting such measurements outdoors, this was a necessary limitation. However, it does limit the extent to which one can be confident of the transferability of skills and knowledge in the current study. The important topic of transfer and representative design of the practice environment has been discussed in more depth elsewhere (Guignard et al., 2020).

Finally, a clear limitation of the experimental design was the lack of a control condition or group of children that did not receive the open water education program. As such it is possible that a range of other factors have contributed to the findings. For example, the participants may have simply become more familiar and comfortable with the testing protocol and therefore an order effect led to their improvements in competency. By testing over three months it is also possible that maturational effects contributed to the children's improvements in competency over the important developmental window of 7-11 years of age. Similarly, because the participants' activities were not controlled or monitored between the post-test and retention test, they may have reinforced their learning with additional practice. Given financial constraints and the number of participants tested it was not possible to include a control group or to monitor additional practice activities. Instead some of the findings were contrasted with a previous study (Button et al., 2017) in which children were taught water safety skills in swimming pools. Whilst this was not deemed a valid or suitable comparison to run any statistical analysis, the general trends are of interest, albeit in need of confirmation by future work.

Conclusions

The present study confirmed that the water safety knowledge and skills of young New Zealand children was varied but, overall, quite low (i.e., in relation to minimum competency levels recommended by Water Safety New Zealand). There was strong support for the efficacy of an education program focused on water safety and delivered in open water environments. Children improved their competency in a range of different tasks assessed in a swimming pool. Furthermore, children demonstrated a good level of retention of these skills when assessed three months after the program had concluded. This study provides initial evidence that teaching water safety skills in open water environments may be an effective way to develop foundational aquatic water competencies.

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